NS 547 Concepts in Modern Physics II: Special Relativity and Related Topics

Description: This course explores the foundations of Einstein's Theory of Special Relativity and its applications to our understanding of nuclear and particle physics, and to astronomy and cosmology. The history of the development of our conceptual understanding of space and time, and the pedagogical issues that arise in teaching this material, are addressed.

Times: Mondays 4:30 – 7:00 pm and Fridays 4:30 – 7:30 pm (13 sessions).

Location: Metcalf Center for Science, 590 Commonwealth Ave. Room varies with lab activity and will be announced in advance.

Instructors:

Name	**Office**	**e-mail**	**Phone**
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Grading Components:

- Homework (20%)
- Midterm test (15%)
- Final exam (25%)
- History presentation (10%) and 10-page (double spaced) essay (10%) - individual
- Lesson plan on special relativity (group presentation, 10%) and individual essay (10%), addressing issues raised by relevant physics education research studies.

History: From the historical and philosophical perspectives, our focus in this course will be on the development of the ideas and debates surrounding the development of the atomic bomb. Each member of the class will select an individual (or in some cases two or three people) who played a significant role in the development of the atomic bomb. Both the presentation and the essay should address the following topics:

- Who were they? Cover general biographical information about them.
- What was their scientific contribution? Describe the physics underlying their contribution and describe how it related to the atomic bomb.
- What were their political views?
- What were their thoughts about the ethics of developing this ultimate weapon of mass destruction?
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Lesson Plan: You may or may not teach special relativity in your own classes, but at least some of your students have heard of it and are interested in it. Participants will work in pairs to design a lesson plan to teach a concept in special relativity. In the plan, the issues raised by the education research articles should be addressed.

Books

Spacetime Physics by E.F. Taylor and J. A. Wheeler, second edition, Freeman. Available from Amazon.

The Making of the Atomic Bomb, by Richard Rhodes, Simon & Schuster. Available from Amazon.

Course web site: http://physics.bu.edu/~duffy/NS547.html and http://itop.pbwiki.com

Course and Program Expectations

We have three basic expectations for each course:

- Regular attendance – you are expected to miss no more than two sessions.
- Arriving on time – you are expected to be present at the beginning of every session, and should not be late more than twice.
- Completing assigned work – you should make a good-faith effort to complete all assignments on time.

The course is run as a community of learners interacting among themselves and with the instructors. The above expectations reflect the fact that the community functions best when all its members are actively engaged in the learning process.

Makeup policy: It is your responsibility to take all quizzes/exams and submit all homework and written work according to the posted schedules. The penalty for late work is 20% of the grade per each session late, unless alternate arrangements have been made with the instructor.

Collaboration: You are encouraged to discuss issues related to homework and written assignments with others, including your classmates, but all work you submit should be your own.

Ethics policy: You are expected to be familiar with and adhere to the College of Arts and Sciences Academic Conduct Code. In particular, cheating on exams and quizzes will not be tolerated. Evidence of cheating will be reported immediately to the Dean's Office. Students found guilty of cheating on exams may be penalized by suspension or even expulsion.

Objectives and Goals

The goal of this course is to support the development of a mastery of fundamental physics with deep pedagogical content knowledge for teachers of physics. The immediate objectives are:

1. Provide a review and instruction of Einstein's Theory of Special Relativity and its applications to our understanding of nuclear and particle physics, and to astronomy and cosmology.

2. Offer participants an historical and philosophical context for the topics covered so as to help them develop the analogies, metaphors, and direct examples that, in part, constitute the basis for a teacher's pedagogical content knowledge.

3. Help prepare teacher participants to take the Massachusetts Teachers Educational Licensure examination in physics.

Curriculum

There will be thirteen class sessions, each 2.5 - 3 hours in length. The typical session will be a mix of laboratory experiments, discussion centered around concepts; a problem-solving session; and either a discussion of the history and philosophy of science, or a discussion of the science education research literature and its bearing on the teaching of physics.

Bibliography

Selections from Physics Education Research Literature

Scherr, R., Schaffer,P & Vokos, S. (2002). The challenge of changing deeply held student beliefs about the relativity of simultaneity. *American Journal of Physics*, *70* (2), 1238-1248.

Scherr, R., Schaffer,P & Vokos, S. (2001). Student understanding of time in special relativity: Simultaneity and reference frames**.** American Journal of Physics,*69* (S1), S24-S35.

NS 547 Course Schedule

Mon. Mar. 5 Session 1: Units of Measurement for Spacetime Physics.

Spacetime Physics: Chapter 1.
Assignment: Selected problems - Chapter 1.
Reading Assignment for Session 2:
Making of the Atomic Bomb: Chapter 2

Fri. Mar. 9 Session 2: Inertial Frames and Measuring Time.

Spacetime Physics: Chapter 2.
Assignment: Selected problems - Chapter 2.
Reading Assignment for Session 3:
Making of the Atomic Bomb: Chapter 3

Mon. Mar. 12 Session 3: The Principle of Relativity

Spacetime Physics: Chapter 3.
Assignment: Selected problems - Chapter 3.
Reading assignment for session 5:

- Scherr, R., Schaffer,P & Vokos, S. (2002). The challenge of changing deeply held student beliefs about the relativity of simultaneity. *American Journal of Physics, 70* (2), 1238-1248.

- Scherr, R., Schaffer,P & Vokos, S. (2001). Student understanding of time in special relativity: Simultaneity and reference frames**.** American Journal of Physics,*69* (S1), S24-S35.

Making of the Atomic Bomb: Chapter 5

Fri. Mar. 16 Session 4: The Lorentz Transformation.

Spacetime Physics: Special Topic: Lorentz Transformation.
Assignment: Selected problems on Lorentz transformation.
Reading Assignment for Session 5:
Making of the Atomic Bomb: Chapter 6

Fri. Mar. 23 Session 5: Lorentz transformations, Simultaneity, Twin Paradox.

Spacetime Physics: Chapter 4.
Mathematics and Problem-Solving: The mathematics of transformations.
Assignment: Selected problems - Chapter 4.
Philosophy/History/Education Research: Misconceptions on simultaneity and reference frames.
Reading Assignment for Session 6:
Making of the Atomic Bomb: Chapter 8

Mon. Mar. 26 Session 6: The Worldline and a Spacetime Map

Spacetime Physics: Chapter 5.
Assignment: Selected problems - Chapter 5.
Reading Assignment for Session 7:
Making of the Atomic Bomb: Chapter 10

Fri. Mar. 30 Session 7: Regions of Spacetime

Spacetime Physics: Chapter 6.
Assignment: Selected problems - Chapter 6.
Reading Assignment for Session 8:
Making of the Atomic Bomb: Chapter 11

Mon. Apr. 2 Session 8: Momentum and Energy: Four Vectors and Momenergy

Midterm test
Spacetime Physics: Chapter 7.
Assignment: Selected problems - Chapter 7.
Philosophy/History/Education Research: Students' presentations
Reading Assignment for Session 9:
Making of the Atomic Bomb: Chapter 13

Mon. Apr. 9 Session 9: Equivalence of Mass and Energy.

Spacetime Physics: Chapter 8.
Concepts: $E=mc^2$, fission, fusion, annihilation.
Assignment: Selected problems - Chapter 8.
Philosophy/History/Education Research: Students' presentations
Reading Assignment for Session 10:
Making of the Atomic Bomb: Chapter 15 (p. 486-496)

Fri. Apr. 13 Session 10: Applications of Energy and Mass Equivalence.

Assignment: More selected problems - Chapter 8.
Philosophy/History/Education Research: Students' presentations

Mon. Apr. 23 Session 11: Gravity: Curved Spacetime in Action

Spacetime Physics: Chapter 9.
Assignment: Selected problems - Chapter 9.
Philosophy/History/Education Research: Students' presentations

Fri. Apr. 27 Session 12: Cosmology.

Philosophy/History/Education Research: Students' presentations
Take home exam

Mon. Apr. 30 Session 13: Wrap up

Philosophy/History/Education Research: Students' presentations
Course evaluation

No class on: Monday March 19, Friday April 6, Monday April 16, Friday April 20